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Original Contribution

Postoperative complications in patients with obstructive sleep apnea: a meta-analysis☆,☆☆

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Abstract
Study Objective: To determine whether a diagnosis of obstructive sleep apnea (OSA) imparts an increased risk of postoperative respiratory failure, cardiac events, and intensive care unit (ICU) transfer than patients with no OSA diagnosis.
Design: Systematic review and meta-analysis.
Setting: Academic Veterans Affairs Medical Center.
Measurements: PubMed, EMBASE, CINAHL, and ISI Web of Knowledge databases were searched through April 2013 for studies that examined the relationship between OSA and postoperative respiratory and cardiac complications among adults. Either fixed or random-effects models were used to calculate the pooled risk estimates. Sensitivity analysis was conducted to examine the robustness of pooled outcomes.
Main Results: Seventeen studies with a total of 7,162 patients were included. Overall, OSA was associated with significant increase in risk of respiratory failure [odds ratio (OR) 2.42; 95% confidence intervals (CI) 1.53 - 3.84; $P = 0.0002$] and cardiac events postoperatively (OR = 1.63; 95% CI 1.16 - 2.29; $P = 0.005$). Heterogeneity was low for these outcomes ($I^2 = 5\%$ and 0%, respectively). ICU transfer occurred also more frequently in patients with OSA (OR 2.46; 95% CI 1.29 - 4.68; $P = 0.006$). These results did not materially change in the sensitivity analyses according to various inclusion criteria.

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Conclusions: Surgical patients with OSA are at increased risk of postoperative respiratory failure, cardiac events, and ICU transfer.

1. Introduction

Obstructive sleep apnea (OSA) is a chronic disorder characterized by frequent reduction or complete cessation of airflow during sleep as a result of obstruction of the upper airway. This altered breathing pattern results in oxygen desaturation and hypercapnia that are terminated by cortical microarousals in an attempt to restore upper airway patency [1]. This pattern of repetitive hypoxemia and nocturnal hypoxemia is implicated in multitude of cardiopulmonary complications in the perioperative period such as hypoxemia, cardiac arrhythmias, myocardial injury, unanticipated admission to the intensive care unit (ICU), and sudden unexpected death [2].

Currently, there are no large epidemiological studies that have been undertaken to determine the prevalence of OSA in the general surgical population; however, reports of several studies suggest that the prevalence of OSA in the surgical population might be higher than in the general population, with variability among different surgical populations [3,4]. A recent study [5] evaluating the prevalence of OSA in general surgical patients undergoing elective non-upper airway surgery found an estimated prevalence of 22% in the adult surgical population. More than 70% of these patients were undiagnosed before presentation for perioperative evaluation. The rate is even higher for morbidly obese patients undergoing bariatric surgery, with reported OSA prevalence exceeding 70% [6,7].

In 2006, the ASA advanced practice guidelines including assessment of patients for possible OSA before surgery and careful postoperative monitoring for those suspected to be at high risk [8]. These guidelines were instituted to minimize the rate of complications in the perioperative period as exposure to sedation, anesthesia, and opioids increase pharyngeal collapse, decrease ventilatory response, and inhibit laryngeal respiratory modulated mechanoreceptors, leading to worsening of sleep apnea [9,10]. Anesthetic medications and benzodiazepines also impair the arousal response, a protective defense mechanism against sleep apnea that helps in overcoming the airway obstruction. Furthermore, coexisting illnesses such as systemic hypertension, insulin resistance, coronary artery disease, and cardiac arrhythmias [11] render the perioperative management of these patients even more complicated.

A recent meta-analysis assessing the risk of sleep apnea on postoperative complications concluded that the incidence of oxygen desaturations, respiratory failure, cardiac events, and ICU transfers was higher in patients with OSA [12]. However, new studies have appeared since its publication, some with conflicting results [13,14]. The aims of this study were to systematically review population-based studies to carry out a meta-analysis to assess the evidence in support of the presence of a relationship between OSA and postoperative complications in patients undergoing elective surgery and to obtain a quantitative estimate of the risk.

2. Materials and methods

This study was exempted from Institutional Review Board approval of the Veterans Affairs Western New York Healthcare System.

2.1. Literature search

The guidelines of the Meta-analysis of Observational Studies in Epidemiology group were followed in performing this meta-analysis [15]. A systematic literature search was performed to identify all studies published before March 2013 that investigated the association between OSA and the risk of postoperative complications. Electronic databases, including PubMed, EMBASE, CINAHL and the ISI Web of Knowledge were searched, using a combination of the following terms: ‘obstructive sleep apnea’ or ‘sleep-disordered breathing’ and ‘postoperative’, ‘complications’ or ‘outcome’, ‘perioperative care’, ‘intraoperative care’, ‘perioperative complications’, ‘outcome’, ‘risk’, ‘morbidity’, ‘mortality’ and ‘death’. The reference lists from relevant publications were also checked for additional publications that might be appropriate for inclusion in the meta-analysis. No language or time restrictions were imposed. Only published full-text articles were searched.

2.2. Study selection

An initial review of title and abstracts were conducted with a full-text review of the articles if there was uncertainty about relevance. Studies were considered eligible for analysis if they met the following criteria: 1) observational cohort studies (retrospective and prospective) or case control studies consisting of adult patients (age $\geq$ 18 yrs); and 2) the exposed population represented cases of OSA diagnosed by polysomnography, overnight oximetry, or screening questionnaire. We excluded studies that did not include a control group or report on postoperative complications. Experimental or laboratory-based studies were also excluded.

All selected articles that appeared to fit the inclusion criteria were identified for full review by three investigators (FH, LV, and JP). Each reviewer independently selected studies for inclusion in the review. Disagreement between the three extracting authors was resolved by consensus.

2.3. Data extraction and quality assessment

Data were extracted from each selected article using standard electronic sheets. The following information was abstracted: last name of the first author, publication year, country where the study was conducted, and age, gender, body mass index (BMI), type of surgery, and the number of patients per arm. The following outcomes were also extracted from each study: 1) acute respiratory failure, defined as the need for prolonged mechanical ventilation (>24 hrs), endotracheal reintubation, or institution of noninvasive mechanical ventilation; 2) cardiac complications, defined as myocardial ischemia or infarction, new-onset arrhythmias, or cardiac arrest; and 3) postoperative ICU transfer. The primary outcome chosen was postoperative respiratory failure and secondary outcomes included postoperative cardiac events and unplanned ICU transfer.

Study quality for the cohort studies was assessed according to the instrument developed by Downs and Black [16]. Each study was scored based on 6 characteristics related to reporting, external validity, selection bias, and power. A priori scores ≥ 23 were considered high-quality studies, ≥ 18 to < 23 intermediate quality, and < 18 low quality. We also conducted an analysis for the *Proteus* phenomenon (ie, appearance of an early extreme result that is refuted by later research) to ensure the integrity of our conclusions [17].

2.4. Statistical analysis

Outcome results are expressed as odds ratios [ORs; 95% confidence intervals (CI)]. Summary estimates were pooled by using the DerSimonian and Laird methodology [18]. Statistical heterogeneity across trials was estimated using the I^2 statistic [19], with $I^2 < 30\%$ denoting low heterogeneity; $I^2 = 30\% - 50\%$, moderate heterogeneity; and $I^2 > 50\%$, substantial heterogeneity. All analyses are shown using the fixed-effects model, unless significant heterogeneity ($P < 0.1$) was present, in which case we used a random-effects model. Egger regression and Begg and Mazumdar methods [20] were used to evaluate publication bias. A two-tailed P-value < 0.05 was considered statistically significant for all the analyses. Sensitivity analysis was performed by recalculating the summary statistics after removing single studies or groups of studies from the analysis, based on characteristics of the study design, outcomes, and quality score. RevMan 5.2 software was used for statistical analysis [Review Manager (RevMan). Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration, 2012].

3. Results

3.1. Study selection

Our search returned 6,314 citations from biomedical databases. After the initial screening of title and abstract, 38 citations were selected for full-text review. A total of 21 citations were further excluded for missing outcome data (n = 9), surgical treatment for sleep apnea (n = 7), no comparison arm (n = 4), and duplicate record (n = 1). Seventeen full-text publications were eligible for this meta-analysis [13,14,21–35] (Table 1). The flow chart of literature search and detailed exclusion reasons are shown in Fig. 1.

3.2. Study characteristics

Fifteen studies were from North America [13,21–32,34,35], one from Europe [14], and one from Asia [33]. Sixteen studies were cohort studies (11 retrospective, 5 prospective), and one was a randomized controlled trial (RCT) [13]. Fourteen of the studies were of intermediate quality (Table 2) based on the scoring system used, whereas three studies were of poorer quality. Common quality problems included potential reviewer bias, selection bias, loss of follow-up, and problems with definition of outcomes at the start of the study.

A total of 7,162 unique subjects were available for analysis. Baseline characteristics of the selected studies are shown in Table 1. Patients ranged in age from 55.7 ± 14.4 years in suspected OSA to 50.1 ± 12.6 years for the control group. Men represented 57.9% of the OSA group, with a mean BMI of 38.2 ± 5.5 kg/m^2, while the non-OSA group consisted predominantly of women (53.1%) with a BMI of 27.9 ± 3.1 kg/m^2. There was considerable heterogeneity in the type of surgical procedures performed across the studies included. However, 8 studies analyzed postoperative complications in the context of a single type of surgery: abdominal (n = 1) [21], orthopedic (n = 3) [13,25,33], bariatric (n = 3) [26,31,35], and cardiothoracic (n = 1) [29].

3.3. Pooled analysis

Of the 17 studies included in this meta-analysis, 11 reported increased risk of postoperative complications. Fig. 2 shows the results of random-effects meta-analysis of the relationship between OSA and postoperative respiratory failure. The total number of participants was 5,611, with 138 incident cases. Results from individual studies differed with both positive and negative associations identified. All combined, OSA was associated with increased risk of developing postoperative respiratory failure (OR = 2.42; 95% CI 1.53 - 3.84; $P = 0.0002$). Heterogeneity was low ($I^2 = 5\%$). Removal of any of the studies did not affect significantly the pooled OR. The funnel plot (Fig. 3) was asymmetrical at the base as it was missing studies in the bottom right corner, suggesting the possibility of publication bias, but it was symmetrical at the peak. However, Egger's test suggested the absence of significant publication bias (intercept = −0.730; standard error = 0.662; $P = 0.28$).

Eleven studies investigated the effect of OSA on postoperative cardiac events. These studies represented a total of 3,781 patients, with 324 incident cases. Results of the fixed-effects

Table 1 Characteristics of the studies included in the meta-analysis

Study	Study design	Diagnosis of OSA	Groups	n	Mean age (yrs)	Mean BMI (kg/m^d)	Surgery type
Ahmad et al. [21]	PC	PSG	OSA	31	43	50	Abdominal
			Non-OSA	9	42	48	
Chung et al. [22]	PC	PSG	OSA	147	59	30.4	Orthopedic, general, ENT, ophthalmology, GYN, neurosurgical, urology, plastic
			Non-OSA	64	50	27.9	
Gali et al. [23]	PC	OSA Screening Questionnaire, Sleep Apnea Clinical Score	OSA	115	59.9	36.0	Orthopedic, GYN, genitourinary, ENT, plastic
			Non-OSA	25	58.2	29.9	
Gali et al. [24]	PC	OSA Screening Questionnaire, Sleep Apnea Clinical Score	OSA	221	59.9	35.1	Orthopedic, thoracic, abdominal, GYN, genitourinary, ENT, neurosurgery, plastic, others
			Non-OSA	472	59.6	30.4	
Gupta et al. [25]	RC	84% PSG, 16% nocturnal oximetry	OSA	101	68.1	33.5	Orthopedic
			Non-OSA	101	69.4	30.2	
Hallowell et al. [26]	RC	PSG	OSA	454	NA	NA	Bariatric
			Non-OSA	436	NA	NA	
Hwang et al. [27]	RC	Nocturnal oximetry	OSA	98	55.9	36.5	Orthopedic, thoracic, abdominal, GYN, genitourinary, ENT, cardiothoracic, vascular, neurosurgical, others
			Non-OSA	74	52.7	34.0	
Kaw et al. [28]	RC	PSG	OSA	282	55.9	38.3	Abdominal, ENT, GYN, neurosurgical, orthopedic, thoracic, genitourinary, vascular, others
			Non-OSA	189	46.3	33	
Kaw et al. [29]	RC	PSG	OSA	37	62.9	31.7	Cardiothoracic
			Non-OSA	185	61.8	31.8	
Mador et al. [30]	RC	PSG	OSA	284	62.13	34.6	CABG, cholecystectomy, colorectal surgery, total hip replacement, total knee replacement, prostatectomy
			Non-OSA	86	59.68	31.54	
Nepomnayshy et al. [31]	RC	60% PSG, 40% unknown	OSA	200	NA	NA	Bariatric
			Non-OSA	267	NA	NA	
O'Gorman et al. [13]	RCT	Sleep Apnea Clinical Score	OSA	86	67.2	36.1	Orthopedic
			Non-OSA	52	63.1	30.4	
Pereira et al. [14]	PC	STOP-BANG Questionnaire	OSA	179	63	28	Orthopedic, abdominal, head and neck
			Non-OSA	161	47	24	
Sabers et al. [32]	RC	PSG	OSA	234	57	35.5	Orthopedic, genitourinary, GYN, abdominal, others
			Non-OSA	234	56.9	33.7	
Ursavaş et al. [33]	RC	STOP Questionnaire	OSA	147	52.7	29.4	Orthopedic
			Non-OSA	1259	33.4	23.6	
Vasu et al. [34]	RC	STOP-BANG Questionnaire	OSA	56	64.7	NA	Orthopedic, GYN, abdominal, genitourinary, vascular, ENT, cardiothoracic, others
			Non-OSA	79	53	NA	
Weingarten et al. [35]	RC	PSG	OSA	618	47.6	50.5	Bariatric
			Non-OSA	179	43.3	46.3	

OSA = obstructive sleep apnea, BMI = body mass index, PC = prospective cohort, PSG = polysomnography, ENT = ear, nose, and throat, GYN = gynecological, RC = retrospective cohort, CABG = coronary artery bypass graft.

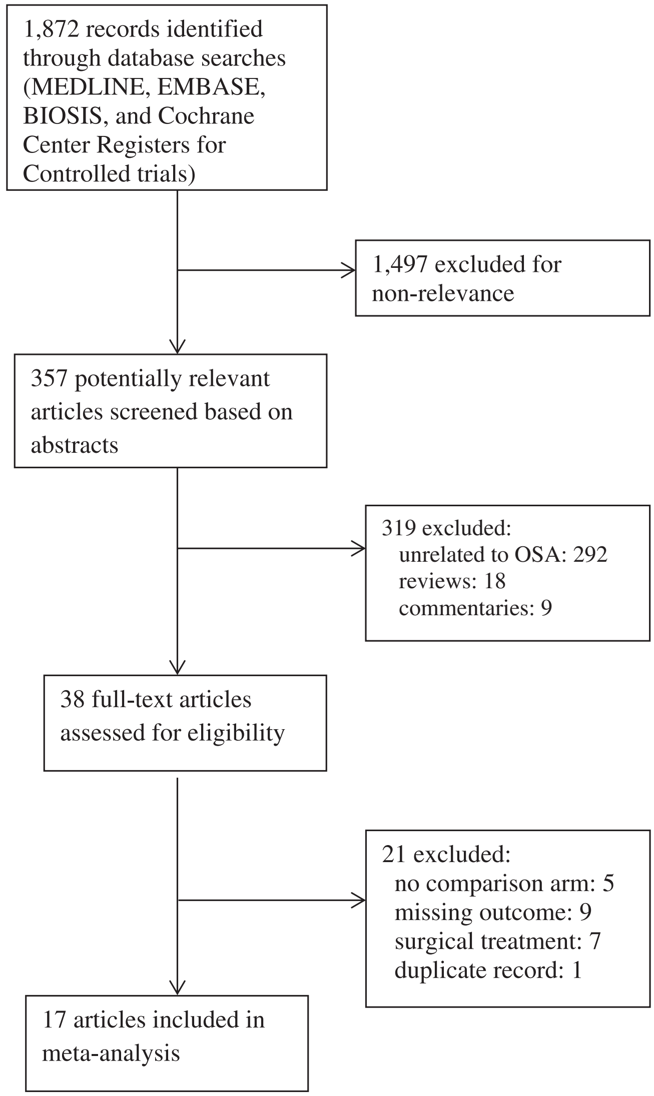

Fig. 1 Flow diagram of study selection process. OSA = obstructive sleep apnea.

meta-analysis are shown in Fig. 4. The majority of the selected studies reported a positive association but none achieved statistical significance for lack of power. However, pooled analysis showed that OSA significantly increased the risk of cardiac events (OR = 1.63; 95% CI 1.16 - 2.29; $P = 0.005$). Heterogeneity was not detected ($I^2 = 0\%$).

Among the 17 selected studies, 9 reported on ICU transfer postoperatively. Together, these studies represented 3,250, patients with 1,746 considered at high risk for sleep apnea. Meta-analysis of these studies demonstrated a higher likelihood for patients with OSA to be transferred to an ICU (OR 2.46; 95% CI 1.29 - 4.68; $P = 0.006$). However, there was substantial heterogeneity ($I^2 = 57\%$) (Fig. 5).

3.4. Sensitivity analysis

Table 3 presents the results of sensitivity analyses according to various inclusion criteria. Overall, the combined risk estimates did not materially change in the sensitivity analyses restricted to studies that used polysomnography for OSA diagnosis, studies that included a single type of surgery, studies that were considered of intermediate or high quality, or retrospective studies. Although the pooled ORs were attenuated in the analysis assessing postoperative cardiac events and ICU transfer, the associations remained significant for postoperative respiratory failure. An analysis for the Proteus phenomenon showed no evidence of such bias ($P = 0.58$).

4. Discussion

Data from the present meta-analysis support the deleterious effect of unrecognized and untreated OSA on postoperative outcomes. Patients with suspected OSA had an almost 2.5 fold risk of developing postoperative respiratory failure, and more than a 1.5 fold risk of

Table 2 Objectives and outcomes of the studies included in the meta-analysis

Study	n	Study aims	Outcomes	Quality score
Ahmad et al. [21]	40	To determine if obese pts with polysomnography-confirmed OSA diagnosis were at significantly greater risk for postop hypoxemic episodes in first 24 hrs after laparoscopic bariatric surgery than morbidly obese pts with no OSA diagnosis.	In the first 24 hrs postoperatively, no difference in median SpO_2 with and without oxygen therapy was noted between OSA and non-OSA groups.	19
Chung et al. [22]	211	To determine good screening tool for OSA before surgery to prevent adverse periop outcomes.	Pts identified as high risk for OSA had significantly increased incidence of postop complications. STOP questionnaire and ASA checklist identified those patients likely to develop postop complications.	20
Gali et al. [23]	140	To identify pts at risk for oxygen desaturation after discharge from PACU.	Pts with high sleep apnea score had higher frequency of oxygen desaturation.	16
Gali et al. [24]	693	To identify pts at high risk of postop oxygen desaturation and respiratory complications using Sleep Apnea Clinical Score (SACS) and postop PACU monitoring.	Postop respiratory events associated with high SACS.	22
Gupta et al. [25]	202	To identify and assess impact of postop complications in pts with unrecognized or known OSA syndrome having hip replacement or knee replacement versus control pts having similar operations.	Higher rates of cardiac events, reintubation, unplanned ICU transfer, and longer hospital LOS noted in OSA group versus group of matched control pts.	20
Hallowell et al. [26]	890	To determine if identifying and treating occult OSA decreases respiratory complications and need for ICU utilization in pts having bariatric surgery.	Aggressive preop treatment of sleep apnea reduced need for respiratory-related ICU stay.	17
Hwang et al. [27]	172	To study relationship of intermittent hypoxemia measured by home nocturnal oximetry with occurrence of postop complications in pts with clinical signs of OSA identified during preop assessment for elective surgery	Higher rates of respiratory, cardiovascular, GI, bleeding complications observed in pts with ODI 4% $\geq$ 5/hr versus ODI 4% < 5/hr, but no difference in hospital LOS noted between the two groups.	22
Kaw et al. [28]	471	To study frequency and nature of postop complications in pts with unrecognized or previously diagnosed OSA having elective noncardiac surgery.	OSA pts are at higher risk of postop hypoxemia, ICU transfers, and hospital LOS.	20
Kaw et al. [29]	222	To study incremental risk of OSA in pts having cardiac surgery.	Higher incidence of encephalopathy, postop infection, and increased ICU LOS were noted in OSA group after cardiac surgery than in those without OSA.	22
Mador et al. [30]	370	To determine if postop complications are increased in OSA pts	Sleep apnea associated with significantly increased rate of postop complications during non-upper airway surgical procedures.	21
Nepomnayshy et al. [30]	467	To evaluate impact of routine preop OSA screening on cardiopulmonary complications between those pts who were and those who were not screened for OSA.	In this study, unscreened morbidly obese pts had no increased incidence of cardiopulmonary complications after surgery versus screened pts.	19
O'Gorman et al. [13]	138	To determine if postop APAP applied to pts at high risk for OSA shortened hospital LOS and reduced postop complications.	No significant difference in primary endpoint, LOS, or any secondary endpoint (ICU transfer, adjustment of oxygen, delirium, new infiltrate or atelectasis) between APAP pts and control group.	21
Pereira et al. [14]	340	To evaluate incidence of PACU admission of surgical pts with STOP-BANG score $\geq$ 3	OSA patients had important incidence among pts scheduled for surgery in our hospital.	19
Sabers et al. [32]	468	To determine whether preop diagnosis of OSA is independent risk factor for periop complications in pts having non-otorhinolaryngologic surgical procedures	No significant difference in rate of unplanned hospital admissions, or respiratory or cardiac adverse events between the two groups.	19
Ursavaş et al. [33]	1,406	To determine, in orthopedic surgery pts, relationship of postop pulmonary complication, snoring, and STOP questionnaire.	No significant difference in prevalence of pneumonia or respiratory failure between low-risk and high-risk groups for OSA.	16

Table 2 (*continued*)

Study	n	Study aims	Outcomes	Quality score
Vasu et al. [34]	135	To determine if high-risk scores on preop STOP-BANG questionnaires during preop evaluation correlated with higher rate of complications of OSA syndrome	Pts at high-risk of sleep apnea based on STOP BANG Questionnaire had higher rate of postop complications and hospital LOS.	21
Weingarten et al. [35]	797	To determine relationship between periop complications and severity of OSA in pts having bariatric surgery	OSA severity was not associated with increased risk of periop complications.	21

Pts = patients, OSA = obstructive sleep apnea, postop = postoperative, periop = perioperative, PACU = Postanesthesia Care Unit, ICU = intensive care unit, LOS = length of stay, APAP = auto-titrating positive airway pressure, preop = preoperative, GI = gastrointestinal, ODI = oxygen desaturation index.

developing a cardiac event than the control group. The presence of OSA was also associated with a 2.5 times higher odds of unplanned transfer to an ICU following surgery.

The results confirm the findings reported by a previous meta-analysis [12] despite the fact that 7 eligible studies have been published since, with three studies supporting an increased risk of adverse postoperative outcomes [14,28,30] and 4 studies against [13,31,33,35]. This enlarged sample size gives credence to the hypothesis linking OSA to adverse postoperative outcomes. The traditional lack of power to detect a significant difference in clinical outcomes from individual studies is mitigated by the fact that our meta-analysis included approximately 7,000 patients. Based on expected respiratory failure rate of 5% in the OSA group [28] and 3.5% in the control group, the sample size had more than 90% power to achieve this difference at a significance level of 0.05 (two tailed). Two recent studies [36,37] involving more than one million patients each identified sleep disordered breathing as an independent risk factor for emergent intubation and invasive and noninvasive ventilation postoperatively. Memtsoudis and colleagues [36] reviewed 2,610,441 entries for orthopedic procedures and 3,441,262 for general surgical procedures performed between 1998 and 2007. Of those, 2.52% and 1.40%, respectively, carried a diagnosis of OSA. Pulmonary complications, including intubation and mechanical ventilation, were more frequently reported in patients with OSA after both surgical procedures than their matched controls [OR 5.20 (95% CI 5.05 - 5.37)] and [OR 1.95 (95% CI 1.91 - 1.98)], respectively. Similarly, Mokhlesi and coworkers [37] examined a total of 1,058,710 hospitalized adult patients undergoing elective surgeries from 2004 to 2008. Sleep disordered breathing was independently associated with a significantly increased OR for emergent intubation [OR 14.3 (95% CI 13.3 - 15.3)] and [OR 10.3 (95% CI 8.0 - 13.3)] and artificial ventilation [OR 3.2 (95% CI 2.9 - 3.5)] and [OR 2.51 (95% CI 1.75 - 3.62)] in orthopedic and prostate categories, respectively. However, these studies have relied on ICD-9 codes to identify patients with sleep apnea, which may have polluted the sample with other sleep disorders. With this realization, we have elected to exclude these studies from the analysis.

The complex mechanisms underlying the increase in respiratory and cardiac complications in OSA patients

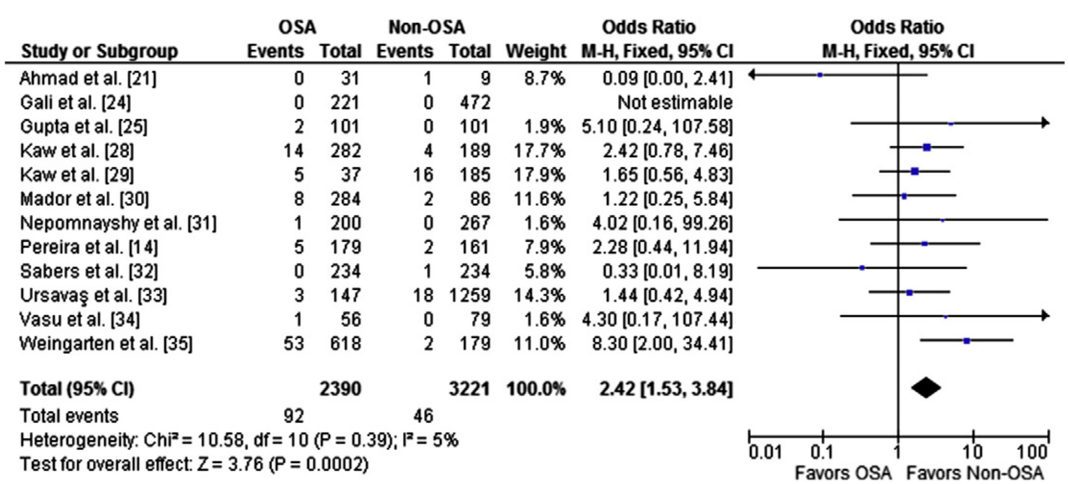

Fig. 2 Fixed-effects meta-analysis of the relationship between obstructive sleep apnea (OSA) and postoperative respiratory failure.

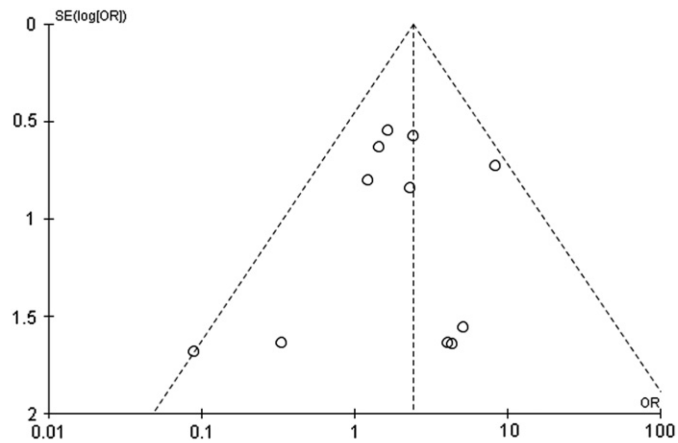

Fig. 3 Funnel plot for the primary outcome of respiratory failure in surgical patients with obstructive sleep apnea (OSA). SE = standard error, OR = odds ratio.

undergoing surgery have been delineated in contemporary reviews [38,39]. Airway obstruction with subsequent hypoxemia is considered the major underpinning of these complications. The inherent collapsibility imparted by the upper airway in patients with OSA is exaggerated by the cocktail of anesthetics and opioids administered in the perioperative period. With the loss of pharyngeal dilator muscles, the negative forces of inspiration accentuate upper airway resistance leading to obstructive events. Given that obesity predominates in OSA, hypoxemia sets in rapidly due to low expiratory reserve volume [40], requiring invasive or noninvasive ventilation and transfer to a higher level of care. A recent meta-analysis confirmed this association by observing more than a twofold increase in frequency of desaturation in patients with OSA compared with those without OSA [12]. Whether these complications are the results of OSA *per se* rather than obesity-associated OSA remains unclear. In a retrospective study of 471 patients undergoing noncardiac surgery, Kaw and colleagues [28] were unable to document a significant association between apnea-hypopnea index and respiratory failure or ICU transfer. Similarly, Sabers et al. [32] could not establish that preoperative diagnosis of OSA was a risk factor for unanticipated hospital admission or respiratory adverse events among patients undergoing outpatient surgical procedures.

Overall, we noted that retrospective studies were more likely to identify a positive association between OSA and major complications postoperatively than those studies conducted prospectively. This phenomenon may be related to confounding variables that cannot be controlled. Another possible source of false positive studies may be publication bias [41]. Publication bias may tend to increase the number of reported positive findings in general. A randomized comparison of screening for OSA versus no screening would provide a more robust evidence for the effectiveness of the screening protocol. However, since the event rate for postoperative complications is low, the required sample size, estimated in thousands, may be cost prohibitive. In addition, the question of denying treatment for patients with documented OSA may raise ethical concerns when the standard of care is shifting toward early intervention despite the lack of conclusive evidence on the efficacy of such a treatment.

Although this study had several strengths, several limitations exist. First, the majority of selected studies

Study or Subgroup	OSA Events	OSA Total	Non-OSA Events	Non-OSA Total	Weight	Odds Ratio M-H, Fixed, 95% CI
Ahmad et al. [21]	0	31	0	9		Not estimable
Chung et al. [22]	10	147	2	64	4.9%	2.26 [0.48, 10.63]
Gali et al. [24]	4	221	9	472	10.7%	0.95 [0.29, 3.11]
Gupta et al. [25]	16	101	9	101	14.4%	1.92 [0.81, 4.58]
Hwang et al. [27]	4	98	1	74	2.1%	3.11 [0.34, 28.39]
Kaw et al. [28]	8	282	0	189	1.1%	11.74 [0.67, 204.55]
Kaw et al. [29]	0	37	2	185	1.6%	0.98 [0.05, 20.80]
Mador et al. [30]	184	284	49	86	50.2%	1.39 [0.85, 2.27]
Sabers et al. [32]	0	234	1	234	2.8%	0.33 [0.01, 8.19]
Vasu et al. [34]	3	56	0	79	0.7%	10.40 [0.53, 205.48]
Weingarten et al. [35]	18	618	4	179	11.4%	1.31 [0.44, 3.93]
Total (95% CI)		**2109**		**1672**	**100.0%**	**1.63 [1.16, 2.29]**
Total events	247		77			

Heterogeneity: Chi² = 6.37, df = 9 (P = 0.70); I² = 0%
Test for overall effect: Z = 2.83 (P = 0.005)

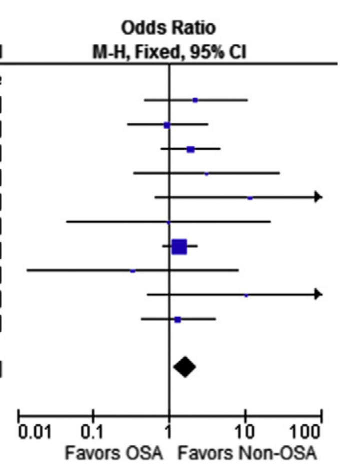

Fig. 4 Fixed effects meta-analysis of the relationship between obstructive sleep apnea (OSA) and postoperative cardiac events.

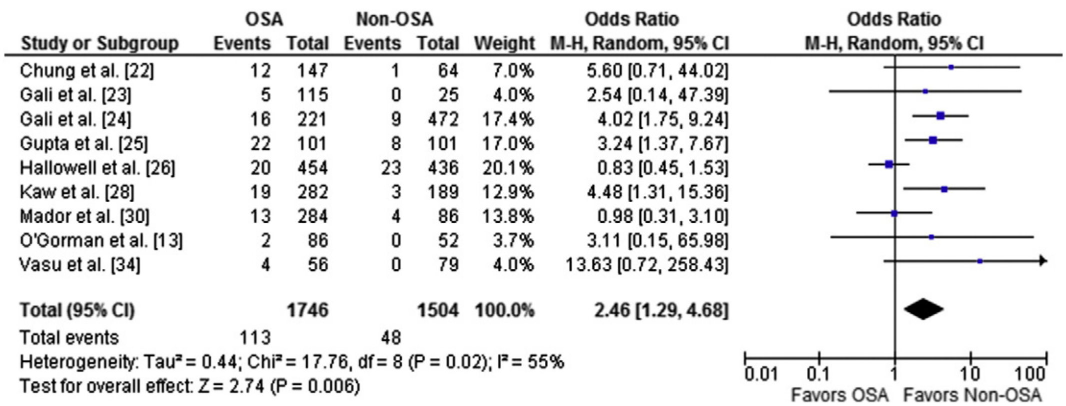

Fig. 5 Random-effects meta-analysis of the relationship between obstructive sleep apnea (OSA) and intensive care unit transfer.

Table 3 Results of sensitivity analysis according to various inclusion criteria

Inclusion criteria	Postop respiratory failure		Postop cardiac events		Postop ICU transfer	
	n	OR (95% CI)	n	OR (95% CI)	n	OR (95% CI)
PSG diagnosed OSA	6	2.48 (1.43 - 4.32)	7	1.54 (1.03 - 2.32)	4	1.72 (0.66 - 4.48)
Single type of surgery	6	2.86 (1.59 - 5.15)	4	1.61 (0.83 - 3.14)	3	1.69 (0.54 - 5.33)
Intermediate to high quality	10	2.56 (1.53 - 4.26)	11	1.63 (1.16 - 2.29)	7	3.33 (2.09 - 5.29)
Retrospective studies	9	2.68 (1.63 - 4.39)	8	1.68 (1.16 - 2.43)	5	2.03 (0.85 - 4.82)
Prospective studies	3	1.14 (0.31 - 4.18)	3	1.36 (0.56 - 3.33)	4	4.01 (1.94 - 8.28)

Postop = postoperative, ICU = intensive care unit, OR = odds ratio, CI = confidence interval, PSG = polysomnography, OSA = obstructive sleep apnea.

were retrospective in nature and therefore were subject to selection bias. Given the non-randomization design, residual confounding due to unmeasured variables could not be fully ruled out; for instance, site and route of anesthesia administration were not considered. Second, differences in different surgical techniques, varying patient populations, changes in defining recurrence, and difficulty with long-term follow-up all hampered firm conclusions. Third, assessment of OSA was based on diverse diagnostic modalities including questionnaires, overnight oximetry, and polysomnography. Moreover, there were also wide variations in the definitions of clinical outcomes. Only three studies [14,28,29] used a standard definition for acute respiratory failure while none presented criteria for ICU transfer. Other limitations included a lack of information on whether the anesthesia and surgical team altered their perioperative management based on OSA diagnosis. A further confounding variable was that 4 studies had patients using continuous positive airway pressure (CPAP) treatment preoperatively and 8 postoperatively. However, not all patients in these studies were receiving CPAP nor was the pattern of use in these patients established. While CPAP use may have altered the risk of postoperative complications, the ultimate impact of these cases on postoperative outcomes is unclear.

In conclusion, surgical patients with OSA may be at higher risk for respiratory and cardiac complications postoperatively, requiring transfer to an intensive care setting. It remains to be determined whether the perioperative risk of OSA patients may be reduced by appropriate screening to detect undiagnosed OSA, and whether implementation of a perioperative management plan for OSA would reduce the morbidity of surgical interventions.

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